HUXMANN

Design of a Reinforced-Concrete Deck-Girder Highway Bridge

Civil Engineering

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1913

DESIGN OF A REINFORCED-CONCRETE DECK-GIRDER HIGHWAY BRIDGE

BY

RICHARD FREDERICK HUXMANN

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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College of Engineering

May 24, 1913.

I recommend that the thesis prepared under my supervision by RICHARD FREDERICK HUXMANN entitled Design of a Reinforced-Concrete Deck-Girder Highway Bridge be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

F. O. Dufour

Asst. Professor of Structural Eng'g.

Recommendation approved

Ira O. Baker.

Head of Department of

Civil Engineering.

DESIGN FOR A HIGHWAY BRIDGE

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A FOUR-SPAN BRIDGE OF
THE TYPE HEREIN DESIGNED

DESIGN OF A HIGHWAY BRIDGE.

I INTRODUCTION

The purpose of this thesis is to design a reinforced concrete highway bridge to replace the condemned steel structure spanning the Sangamon River near Fisher, Illinois.

II THE OLD BRIDGE

The bridge in place is of the bowstring type and consists of a two-span continuous truss, with spans of ninety nine feet each. The central supports are steel bents. Though very good abutments have been built, they have not been used to carry the main spans. The south end of this span is fifty feet from the abutment, and the roadway is carried over this span by a pony truss. On the north end, the roadway is carried over an eight-foot space by means of I-beams. Fig. 1 gives the sections and general dimensions.

The site of the bridge is about one-half mile south of Fisher, Illinois. The waterway is a shallow stream for the greater part of the year, but carries a comparitively large quantity of water during the flood seasons. At low water the stream is about sixty-two feet wide and flows entirely under the north half of the present structure. The purpose of the long bridge is not merely to span the stream but to allow sufficient waterway at flood seasons. The roadways approaching the bridge have been elevated to make traffic possible during high water. See Fig. 2, page 4.

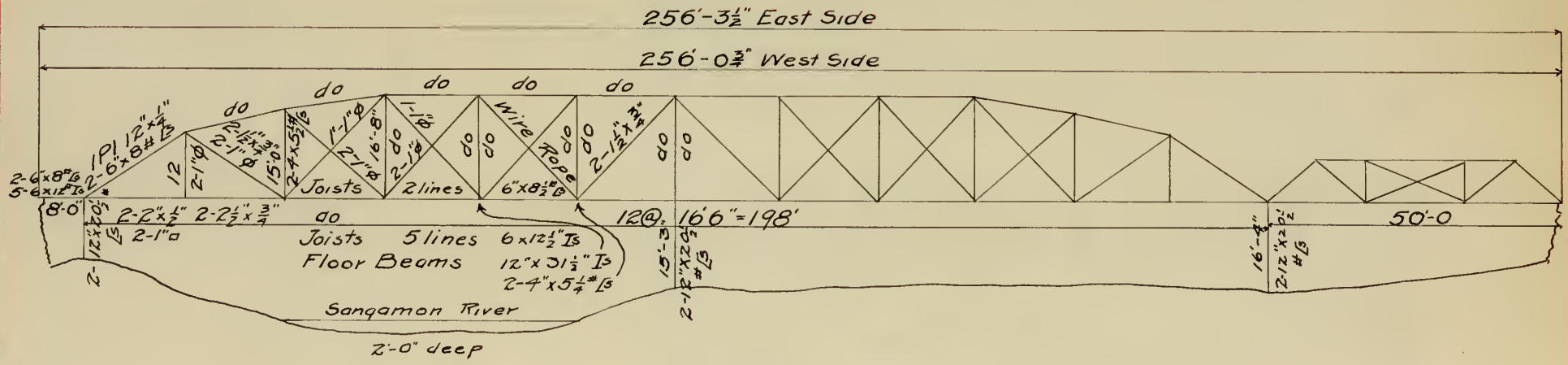


Fig. 1 Dimensions of Old Bridge.

III THE NEW BRIDGE

Art. 1. Site.

The new bridge is to be built on the same site and in the same position as the old, and the old abutments will be used to carry the two end spans of the new bridge.

Art. 2. Type of Bridge.

The type of bridge to replace the old structure is the important consideration. The reinforced concrete slab and girder type will be used. The reasons for this are several. A steel bridge is objectionable on account of transportation facilities. The road from Fisher to the bridge site is bad and almost impassable to a heavy load in rainy weather. The reinforcing steel used in a reinforced concrete bridge can be carried in any quantity desired, as can the concrete. Concrete arches cannot be used as the low lying and soft soil will not permit the heavy bearing produced by an arch. Arches will require more material in themselves and more lumber for their forms and their bracing. See Fig. 2.

Art. 3. Dimensions.

The length of span, using the old abutments, is 256 feet and 3 inches. Five spans of 51 feet and 3 inches will be used in this design. This will necessitate the construction of four piers. The roadway is to be 16 feet in the clear. See Fig. 3.

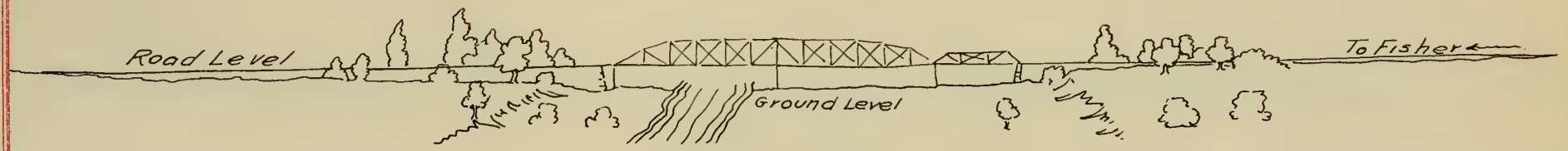


Fig 2 Showing Low Lying Ground at Bridge.

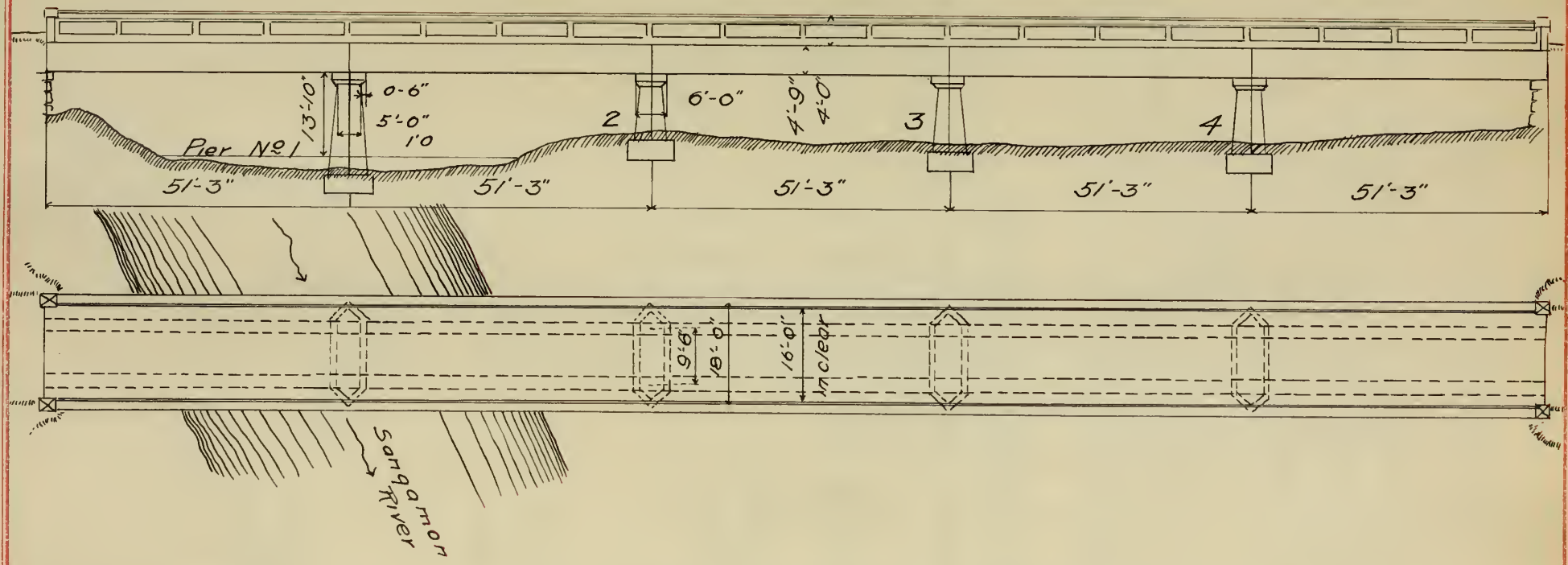


Fig. 3 General Dimensions of New Bridge.

Art. 4. Contract and Specifications.

In case any structure is to be built it is advisable to furnish notices to bidders as well as a contract and specifications. The following is a generally accepted form.

NOTICE.

Contractors are particularly requested to examine the plans, specifications, and site of the work before bidding.

CONTRACT AND SPECIFICATIONS.

Covering the construction of a Reinforced Concrete Deck Girder Highway Bridge across the Sangamon River between Condit and Newcomb Townships, near Fisher, Champaign County, Illinois.

C. L. Duvall)
) Commissioners
L. F. Putnam)
) Condit Township
H. M. Schwartz)

E. Ressler
Clerk

Geo; Robinett)
) Commissioners
J. Williams)
) Newcomb County
A. Kroner)

R. L. Myers
Clerk

D. J. Holtermann)
) Supervisors
C. W. Witt)
) Champaign County
J. J. Hayward)

R. F. Huxmann
Engineer

TO BIDDERS

Sealed proposals endorsed with the title of the work to which they relate, and the name and residence of the Proposer, will be received by the County Clerk of Champaign County, Illinois, up to 2 o'clock P.M., September 15, 1913, for the construction of a reinforced concrete arch deck girder highway bridge across Sangamon River, between Condit and Newcomb Townships, near Fisher, Champaign County, Illinois.

Contractors will bid as follows:

1. The lump sum price for furnishing, and erecting complete, including all grading ready for travel one bridge consisting of five fifty-one-foot three-inch (51 feet 3 inches) reinforced concrete deck girder spans, four piers, minor work on two abutments, and the removal and disposition of the present bridge superstructure and steel sub-structure bents.

2. The price per lineal foot in place for piles ten (10) to twelve (12) inches in diameter and fifteen (15) twenty (20) and thirty (30) feet long.

3. In case of any variations in the amount of concrete masonry from that shown on the plans, an adjustment shall be made on a basis of _____($) per cubic yard for masonry in foundations, and _____ _____($) per cubic yard for masonry above foundations for any increases or deductions authorized by the engineer or the party of the first part.

The above price to include the furnishing and doing of

each and everything required to be furnished and done by the drawings, specifications and contract.

All materials furnished must be of the best quality of the kind called for, and all work alone in accordance with the drawings, specifications and contract.

Each bid must be accompanied by a properly certified check for the sum of one hundred dollars ($100.00) payable to the order of the Commissioners of Condit and Newcomb Townships, Champaign County, Illinois, which will be returned to the bidder, unless forfeited, as hereinafter provided, and no bid will be considered which is not accompanied by such check.

A bond will be required for the faithful performance of the contract, in such sum as shall be fixed by the Commissioners after the bids are opened; said sum to be of twice the amount of the contract, the sureties to be residents of Illinois, and approved by the Commissioners.

The contract must be signed within six days (Sunday excepted) after the date of notification by the undersigned, of the acceptance of the bid and the readiness of the contract for signature, and in case of the failure of the bidder after such notifications to execute the contract within said time, the proposal shall be considered as having been abandoned, and the certified check accompanying the bid shall be forfeited to the said Commissioners as liquidated damages for such abandonment.

The commissioners reserve the right to reject any and all

bids should they deem it advisable to do so.

Bidders are cautioned to read carefully the contract and specifications.

By order of the Commissioners of
Condit and Newcomb Townships,
Champaign County, Illinois.

Champaign, Ill.

April 29, 1913.

CONTRACT AND SPECIFICATIONS.

Covering the construction of a reinforced concrete deck girder bridge across Sangamon River, between Condit and Newcomb Townships, near Fisher, Champaign County, Illinois.

.....

This agreement made and entered into this _____ day of _____ in the year One thousand nine hundred and fourteen by and between _____ parties of the first part, and _____ _____ hereinafter known as the Contractor, party of the second part.

Witnesseth: That the parties to these presents, each in consideration of the undertakings, promises and agreements on the part and behalf of the other herein contained, have undertaken and agreed and do hereby undertake and agree, the parties of the first part for themselves, and their successors, and the party of the second part for _____, _____ heirs, executors, administrators, or assigns as follows:

(A) The contractor, in consideration of the sum _____ _____ Dollars and _____cents ($) to be paid in the manner hereinafter provided, shall and will furnish all the tools, machinery, material and labor at his own cost and expense, necessary or proper for the purpose of constructing and completion, and shall and will construct, furnish and complete, ready for use, the reinforced concrete deck girder bridge across the Sangamon River, between Condit and Newcomb Townships near Fisher, Champaign County,

Illinois, in accordance with the plans and specifications of the parties of the first part, governing said work.

The contractor further agrees, if required by the parties of the first part to furnish and put in place complete, piles not less than ten inches at the butts, for the following prices.

Pile 15 ft. long _____ cents per lineal foot in place

" 20 ft. " _____ " " " " " "

" 30 " " _____ " " " " " "

In case of any variation in the amount of concrete masonry from that shown on the plans an adjustment shall be made on a basis of _____ _($) per cubic yard for masonry in foundations, and _____ ($) per cubic yard for masonry above foundations, for any increases or deductions authorized by the Engineer or the party of the first part.

(B) The said contractor shall furnish all the said materials and perform all of said labor, and fully construct, finish and complete said bridge and do all grading in strict compliance wity the plans and specifications for said work on file in the Office of the County Clerk of Champaign County, Illinois; and the specifications hereunto annexed, and construct said bridge in a good and workmanlike manner within the time required by paragraph J.

(C) The parties of the first part agree to pay the Contractor the consideration hereinbefore expressed when said bridge has been inspected and approved and accepted as required by law.

(D) It is further expressly agreed that all the work, labor and material which shall be done and furnished in and about the work called for by this contract, drawings and specifications, shall be done and furnished strictly pursuant and in conformity to the following specifications, unless expressly stated in writing to the contrary by the Commissioners of Condit and Newcomb Townships.

(E) And it is further understood and agreed that all work provided to be done under this agreement shall be of the best character, and shall be made complete and satisfactory before acceptance.

(F) And it is further understood and agreed that the Contractor shall assume all responsibility of every kind and description. The Commissioners and Supervisors shall not be held to any responsibility for any accident or for any damage whatsoever, or for the violation of any law, or ordinance, or for the payment of any fees, and the Contractor must protect the Commissioners and Supervisors against all such liability.

(G) And it is further understood and agreed that the Contractor shall assume all risks from floods, storms, damages arising out of the nature of the work, or for any unforeseen or unknown or unusual obstruction or difficulties which may be encountered in the prosecution of the same until final acceptance of the bridge by the proper authorities.

(H) And it is further agreed and understood that the contractor shall take, use, probide, and amke all proper, necessary and sufficient precautions, safe-guards and protection

against the occurrence or happening of any accident, injuries, damages or hurt to any person or persons during the progress of the work herein specified, and to save harmless the Commissioners and Supervisors, their officers, agents, and servants, from the payment of all sums of money by reason of all or any such accidents, injuries, damages or hurts, that may happen or occur about such work.

(I) And it is further understood and agreed in the event of the Commissioners and Supervisors by their Engineer deciding that these specifications and contract are not being properly fulfilled, bot as to care shown, quality of material used, workmanship and promptitude in execution; or if the contractor becomes bankrupt or insolvent or assigns _____ property for the benefit of _____ creditors, or shall become otherwise unable to carry out the work, or shall neglect or refuse to promote the work with such dispatch as is thought proper by the Engineer, then the Commissioners and Supervisors will have the right to empower their engineer to contract with or employ such other person or persons as he or the Commissioners and Supervisors may see fit, to finish and complete the several unfinished portions of the work, first giving notice to the contractor in writing of such intention, three days before employing such person or persons, such notice to be served upon the contractor, either personally or by leaving such notice at his residence or with his agent in charge of the work.

The cost to the Commissioners and Supervisors of any such work that may be executed or constructed for under this clause shall be deducted from the moneys that may be due, or may at any time thereafter become due to the contractor, the contractor hereby waiving all claims for damages.

(J) The contractor will commence work herein agreed to be performed by him within ten days from the date of the contract, and will execute all work, in every respect, in a thorough and workmanlike manner and will fully perform and complete all of the work which he has agreed to perform on or before September 1st, 1914.

In case of failure on the part of the contractor to complete all the work in the time heretofore stated and agreed upon, he shall pay to the parties of the first part, as liquidated damages and not as a penalty, the sum of twenty-five dollars ($25.00) per day for each and every day after September 1st, 1913, until the actual time of completion of the entire work.

(K) The contractor is to make himself sure in regard to the estimate of quantities and any weight there given since no responsibility in regard to this is assumed by the parties of the first part.

_____)
_____) Commissioners
_____) of
_____) Condit Township
_____)

_____)
_____) Commissioners
_____) of
_____) Newcomb Township
_____)

_____)
_____) Supervisors
_____) of
_____) Champaign County
_____)

_____(Seal)
Contractor

Approved as to legal form

_____
County Attorney.

SPECIFICATIONS

Covering the Construction of a Reinforced Concrete Deck Girder Highway Bridge across the Sangamon River between Condit and Newcomb Townships near Fisher, Champaign County, Illinois.

PLANS AND SPECIFICATIONS.

The work shall be constructed according to the plans and these specifications, both of which shall be considered a part of the contract. They contemplate a complete structure and any error or ommission in plans and specifications shall not release the contractor from building a structure complete.

OLD STRUCTURE.

The Contractor shall remove the old bridge at site, to provide a satisfactory site for the new structure and is to pile it up near the site as directed by the engineer. He is to have full use of the old bridge in the erection of the new structure; and must remodel the old abutments and wings according to the plans.

TRAVEL.

The contractor to provide a suitable place for travel through the river-bed during the construction.

LINES AND STAKES.

Before commencing excavations it will be the duty of the contractor to notify the Engineer, who will give him center line and stakes and the new structure shall be constructed true to the lines shown upon

the plan and as such staked out by the Engineer.

FOREMEN AND WORKMEN.

The Contractor shall at all times have a competent foreman on the work or some authorized agent upon whom notice may be served and orders issued for the conduct of the work. He shall employ only competent workmen and shall in all cases give the citizens of Champaign County, the preference.

EXCAVATIONS AND FOUNDATIONS.

Excavations for foundstions shall be made by the Contractor to a depth of foundation line as shown on plan, or if compact gravel, rock or sand is reached before, he shall notify the engineer and do as directed in writing by the Engineer after he (the engineer) views the excavations. After going to the depth indicated on the plans the Engineer is to be notified, and in case he thinks it desirable the Contractor shall drive piles as directed.

FORMS.

The contractor shall provide the forms for the support of the girders of sufficient strength to hold the concrete until firmly set. Uprights must be so solidly formed that they will not give or settle during construc tion of the work.

All forms coming in contact with the exposed surfaces shall be smoothly planed and shall be made non-absorbent by saturation with water. Soap or

paraffine may be used to prevent adherence of the concrete to the forms. They must be sufficiently braced and wired to prevent bulging.

CORNERS.

All corners of concrete shall be rounded off by moulding or trowel, so that no sharp edges appear in exposed places to be broken off.

ENFORCEMENT.

Shall be of open-hearth medium steel of corrugated bars. They shall be free from paint, oil or scales before imbedding in the concrete and shall be imbedded to a depth of at least one inch. The sizes and spacing of rods is clearly shown on plan which plan will become a part of the contract.

Bars shall be tied together with wire and otherwise rigidly secured to their proper position before concrete is placed.

CONCRETE.

Shall be composed of true Portland Cement, clean sharp sand, and hard broken stone or gravel.

CEMENT.

The cement shall be approved by the engineer, Universal Portland Cement or any Portland Cement of equally good quality and shall withstand the following tests. FINENESS - at least 99% shall pass a No. 50 sieve, 92% shall pass a No. 100 sieve, and 75% shall pass a No. 200 sieve. TENSILE TESTS. The cement shall pass tests satisfactory to the Engineer in Charge of construction, but neat briquettes with 22% of water

after seven days, being immersed six days, must show a tensile strength of at least 400 lbs. per square inch. Cement mixed neat with enough water to form a stiff paste, shall after thirty minutes at seventy degrees Fahrenheit, be appreciably indented with one-twelfth (1/12) wire loaded to one-quarter pound. Pats of cement neat on glass plates shall not scale or crack when allowed to harden in moist air at 175 degrees Fahrenheit for three hours, and then subjected to boiling water for three days. The Contractor shall provide a store-house at the site of the work for the proper storing and protection of the cement. When possible, it shall be delivered in time to have samples taken and the usual one and seven days tests made. Any cement which may become damaged in transit or by improper care in storing will be rejected by the Engineer or his authorized inspector and the Contractor must promptly remove such rejected cement from the work.

STONE.

Stone shall be tough, clean and hard and shall not be larger in dimensions than one and one-half ($1\frac{1}{2}$) inches for all foundations and piers, nor larger than three-quarters (3/4) inches for all other work.

SAND.

Sand shall be good, sharp, clean, coarse and free from dust, loam, clay, ashes, coal, perishable matter or imporper substances, clean crusher screening may

be substituted for one-half the volume of sand required in the mixture.

MIXED GRAVEL AND SAND.

Gravel shall not be larger than will pass a screen of three inch mesh when used for foundations, piers, and abutments nor larger than three inches for all other work, and shall be thoroughly filled with clean sand containing not in excess of five per cent loam. It shall not be delivered on the site nor used without the written approval of the Engineer in charge after he has carefully examined it to see that it is properly mixed in the right proportions and does not contain excessive foreign matter.

INSPECTION.

All materials shall be subject to inspection and approval according to these plans and specifications and the enginner shall control as to interpretation. The work shall also be subject to the inspection and approval of the Commissioners and Supervisors in accordance with the laws of the Commonwealth, in such cases made and provided.

MIXING.

Mixing of concrete in a thorough manner is the first requirement for securing good concrete. It shall be hand or machine mixed of not more than one cubic yard in one batch. If hand mixed, the sand and cement

shall be mixed to an even color dry, then the stone shall be added and the whole aggregate cut and turned three times, adding while turning sufficient water to make the mass wet.

STONE CONCRETE.

Concrete for all foundations, piers and abutments shall be composed of one part cement, three parts sand, siz parts stone, not larger than will pass through a one and one- half inch ring. All other concrete shall be composed of one part cemtn, two parts sand and four parts of stone not larger than will pass through a three-quarter inch ring. All quantities are to be measured accurately by volume loose.

GRAVEL CONCRETE.

Concrete may be made of naturally mixed sand and gravel in proportions of one part cement to seven parts of naturally mixed, clean river-bed or bank sand and gravel, for foundations, piers and abutments and in proportion of one part of cement to five parts of aggragate for all other concrete work.

PLACING.

Supporting Girders to be built continuously and stopped off at under line of floor slabs. Floor slab shall be built continuously in transverse sections, squaring off at stopping points. After slabs are placed, each railing for each span shall be built continuously. All reinforcing metal must be put in position before placing concrete, and so place that

joints between subsequent sections of concrete are properly bonded.

SPADING. All concrete facing on walls and girders and railings, shall be thoroughly spaded while placing the concrete so that no honey combing shall open on the work.

EXPANSION JOINTS.

Expansion joints will be in the structure wherever shown upon the plans. In case of railings, a beveled vertical timber to form a groove shall be attached to the bulkhead and before the adjoining section is constructed the bulkhead and vertical timber shall be removed against which surface and groove there shall be placed, one layer of hydrex felt, asbestos cloth or heavy paper extending uniformly to within one-half inch of the face of the finished surface.

REMOVING FORMS.

The Contractor shall remove supports and forms at such time as he may determine and at his own wish but not later than sixty days after the completion of the work.

FINISHING.

The face forms must be removed as soon as possible after concrete has taken its initial set, and any patching done while the concrete is green. The faces must be gone over with a smoothing stone and clear water until uneven parts and form marks are removed. The faces must then be washed with clear water and a

stiff brush.

PAVING.

The contractor shall furnish a six-inch layer of earth the full length of the bridge.

GRADING.

Will be made by the contractor and must be done in accordance with the contract and specifications. The filling and grading to be made from a distance of 200 feet from the ends of the bridge.

NAME PLATE.

Two suitable cast-iron tablets shall be prepared for the bridge by the contractor, containing the year constructed, the names as appear on drawing, the contractor's name, and placed where directed by the Engineer.

CLEANING UP.

After the completion of the work the contractor will remove all earth, trees and rubbish and obstructions he has placed in the stream to the full width of the waterway at ordinary level, plus thirty feet each side of same, replace all fences and put property used in as good condition as before work was started.

ENGINEER.

Wherever the word "Engineer" occurs in these specifications it is intended to mean R. F. Huxmann, engineer, for the County Commissioner of Condit and Newcomb Townships, Champaign County, Illinois.

Art. 5. Loads and Stresses.

The dead load consists of the weight of the structure and the loam or sand used for a cashion on the roadway. Limestone concrete will be taken at 150 pounds per cubic foot, and 110 pounds per cubic foot for wet loam.

The live load to be designed for will be a uniform load of 125 pounds per square foot or a 24-ton traction engine on axles spaced 10 feet apart, and wheel 6 feet, C to C, 16 yons on the rear and 8 tons on the front wheels. This load is assumed to act over an area 8 by 12 feet producing 500 pounds pressure per square foot.

For the superstructure, as per specifications, a mixture of 1 : 2 : 3 concrete will be used, and a 1 : 2 : 5 mixture for substructure. Table I below gives ultimate strengths for various proportions and from this table the working stresses for concrete may be determined.

TABLE I. ULTIMATE STRENGTHS OF CONCRETE.

Reference Number	Portland Cement	Sand	Pebbles	Crushing Strength lbs. per sq.in.
(1)	1	2	3	2783
(2)	1	2	5	2414
				Shearing Strength lbs. per sq.in.
(3)	1	2	3	1500
(4)	1	2	5	1200

A factor of safety of 4 will be assumed making the working stress for concrete proportioned as in (1) 700 pounds per square inch and for (2) 600 pounds per square inch.

The values for shear, as given in the table are high and are only obtainable under ideal conditions. For this work an allowable shearing stress of 50 pounds per square inch for concrete proportioned as in (1) and 40 pounds per square inch as in (2). This will give a factor of safety of 30.

For the steel used in reinforcement, a working stress of 16,000 pounds per sqaure inch will be used for tension and compression.

The amount of reinforcement for temperature changes, will be taken as 0.3% of the sectional area, as is the general practice.

Art. 6. Design of Superstructure.

Cantilever Portion of Slab. In the design of the slab one foot only will be considered. The cross sectional area of the railing as shown in Fig. 5 is 2.30 square foot; the volume is 2.30 cubic foot per foot of slab. The weight of concrete being 150 pounds per cubic foot, the weight of the railing is 350 pounds per lineal foot of slab.

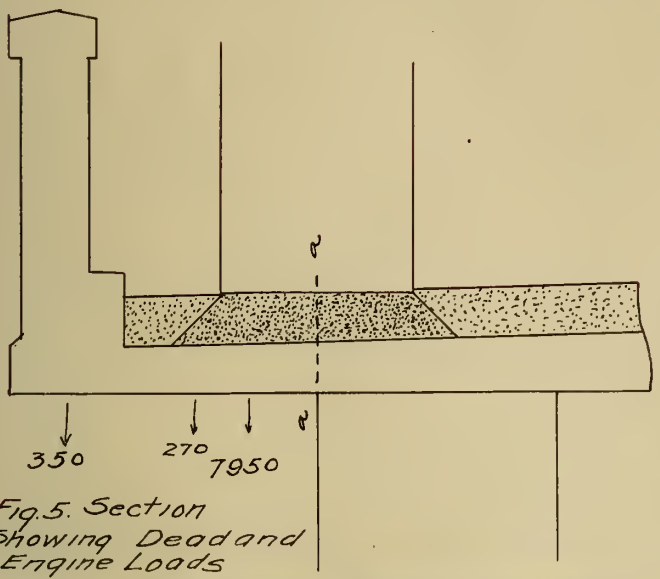
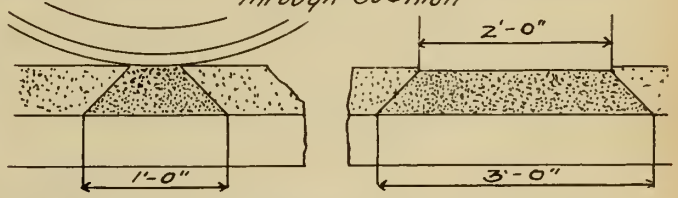


Fig. 5. Section Showing Dead and Engine Loads

The cross sectional area of the slab is 1.06 square feet and the weight per foot of slab is 160 pounds. One cubic foot of earth cushion is on this portion of the slab and weighs 110 pounds.

Fig. 6 Showing transmission of Wheel Load through Cushion



The wheel load of the engine will be asumed to act on the concrete over an area of 1 by 3 feet as indicated by Fig. 6. The load on the wheel is 16,000 pounds and this will produce a load of 5300 pounds per square foot on the concrete. The edge of the wheel will come within one foot of the ground rail, therefore the force due to the wheel load causing moment about the section a---a is $1\frac{1}{2} \times 5300 = 7950$ pounds. The total moment about section a---a is

$$-7,950 \times .75 - 350 \times 2.66 - 110 \times 1$$

$$= -5,990 \text{ lb.-ft.}$$

$$= -72,000 \text{ lb.-in.}$$

For purposes of design all steel will be considered horizontal. The slope of the top surface of the slab is 3 inches in 8 feet, the secant of the angle between this slope and the horizontal is 1.01, by which number any steel sloped as the surface of the slab is, but as this number exceeds unity by only one one hundredth, it will not be considered.

The steel ratio for tensile reinforcement P, will be taken as 1.5% and p', the ratio of the compressive reinforcement as 0.75%. Then K is 0.45 and j, 0.85. The depth d, allowing $1\frac{1}{4}$ inches between the steel and the surface of the concrete, will be 5.5 inches. The ratio $\frac{d'}{d}$ will be assumed as $\frac{1}{10}$, d' being the distance from the compressive face of the slab to the plane of the compressive reinforcement.

The steel when stressed to 16000 pounds per square inch will resist a bending moment of 16000 X .015 X .85 X 12 X 30.3 = 76,000 lb.-in. which is more than sufficient to resist the moment produced by the load described.

The resisting moment of the compressive steel and concrete is

$\frac{1}{2}$X16,000X.45X.85X30.3+16,000X.0075X12X5.5X4.95= 90,200 in.-lb.

The shear at section a---a is equal to 8,310 pounds. The concrete will take 5.5 X 12 X 50 = 3,300 pounds

" " " " 1.5 X 10,000 =15,000

Total 18,300 pounds

So that no other provision need be made for resisting shear. For arrangement of steel see Fig. 6, 7, 8.

For the design of the central portion of the slab, the engine will be considered traveling down the center of the roadway, producing a uniform load of 500 pounds per square foot over

an area of 8 by 12 feet.

Then R. X 9.5 X -350 X 13.22 - 270 X 11.66 - 1,180 X 4.66 - 6.25 X 3500 + 270 X 2.25 + 350 + 3.91 = 0

On the equation, 3,500 pounds is the load produced by the engine on the area 7 by 1 foot between the girders.

$$R. = \frac{33,209}{9.5}$$
$$= 3,500 \text{ pounds.}$$

The moment due to this loading about the center line of the slab is

3,500 X 4.75 - 350 X 8.66 - 270 X 7 - 590 X 1.75 - 1.75 X 1750

= 8,328 lb. ft.

= 100,000 lb.in.

$M = R\ b\ d^2$ b= 12 d= 7.75

100,000 = R X 12 X 53

$$R = \frac{100,000}{630}$$
$$= 159$$

A = .012 X 12 X 7.75
= 1.115

See Fig. 6, 7, 8 for arrangement of steel.

The shear at the section of the slab just inside of the girder is 3,500 - 350 - 270 = 2,880#. There are 93 square inches available to resist shear. The shear per square inch is therefore $\frac{2,880}{93}$ = 30 pounds per square inch which is well within the allowable limit of 50 pounds per square inch.

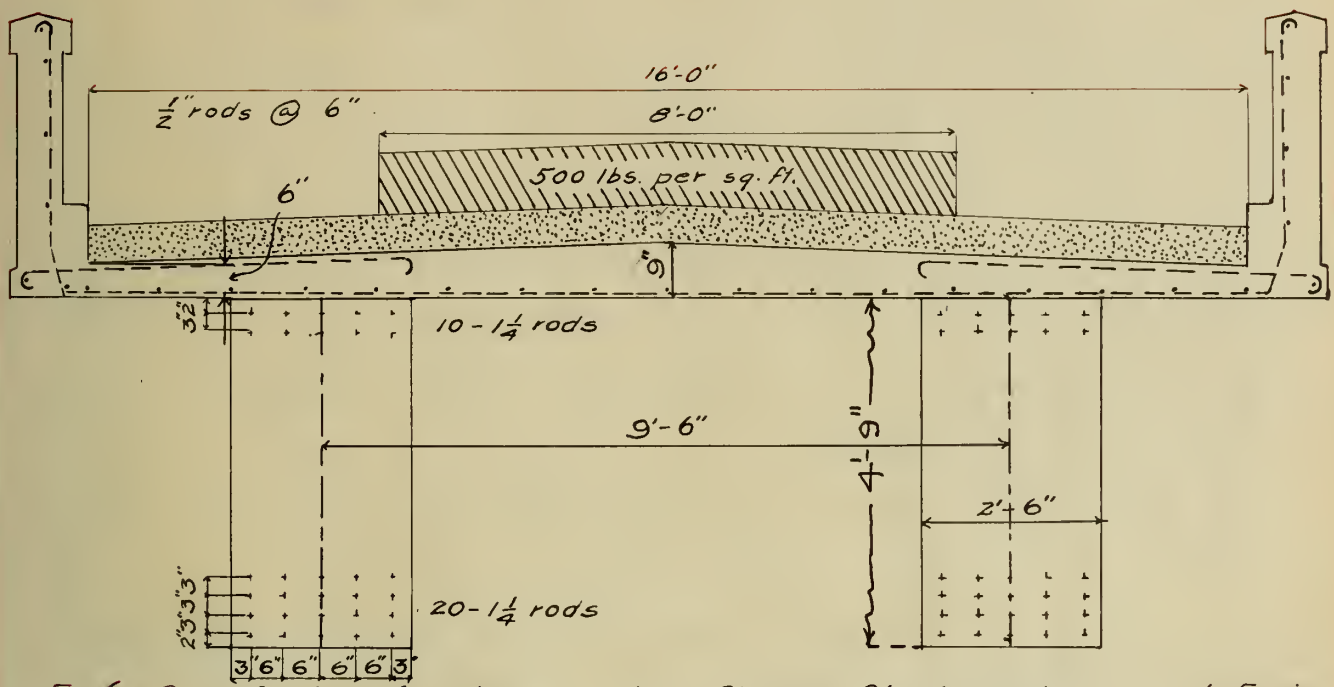


Fig. 6 Cross Section of Slab and Girders Showing Steel and Load Due to Engine.

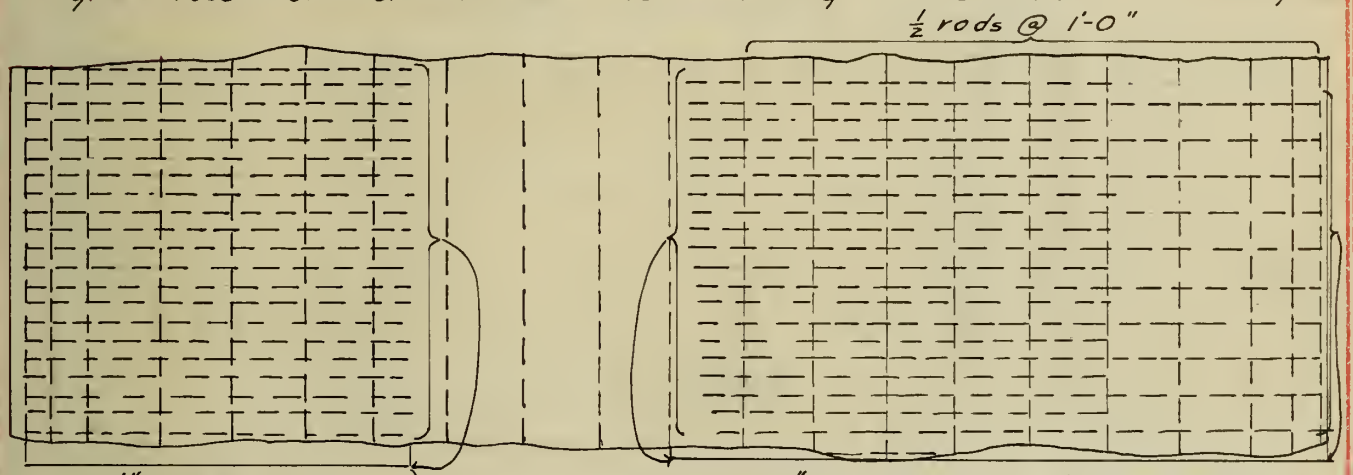


Fig. 7a Fig. 7b

Fig. 7

a Plan of half of slab showing steel in upper portion of slab.
b Plan of half of slab showing steel in lower portion of slab.

Girders.

The engine load on the roadway as stated before will be 48,000 pounds. As the engine runs along the roadway one half foot from the wheel guard, the girder below the engine receives 0.92 of 48,000 or 43,000 pounds. When the engine load is on the center of the span R. for the girder is $\frac{1}{2}$ X 43,000 or 21,500 pounds. The bending moment due to this load is

$$21{,}500 \times \frac{51.25}{2} - 21500 \times 3 = 435{,}000 \text{ lb.-ft.}$$

$$= 5{,}800{,}000 \text{ lb.-in.}$$

The load due to the sand cushion per foot of girder is

$$8 \times .5 \times 110 = 44 \text{ lb.}$$

The load due to the slab and rail per foot of girder is

$$8 \times \frac{6 + 9}{2 \times 12} \times 150 + 350 = 1{,}475 \text{ lb.}$$

The total superimposed dead load is 1,915 lb. per foot of girder.

The weight of the girder per foot is

$$2.5 \times 4.75 \times 155 = 1{,}780 \text{ lb.}$$

The total dead load per foot of girder is 3,695 pounds.

The moment at the center of the girder is

$$\frac{1}{8} Wl^2 = \frac{1}{8} \times 3{,}695 \times \overline{51.25}^2 \times 12$$

$$= 14{,}691{,}600 \text{ lb.-in.}$$

The total monent is 20,491,600 lb. in.

Assuming p = .02, p' = .01 then K = 0.47 and j = 0.83

d will be 53 inches, d', 5.3".

$M_S = F_s A j d$

$= 16{,}000 \times .02 \times .83 \times 30 \times \overline{53}^2$

$= 22{,}382{,}000$ lb.-in.

$M_c = \frac{1}{2} K f_c (1 - 1/3 K) b d^2 + fs' p' b d (d - d')$

$= \frac{1}{2} \times 700 \times .47 \times .84 \times 30 \times 2759 + 16000 \times .01 \times 30 \times 53 \times 47$

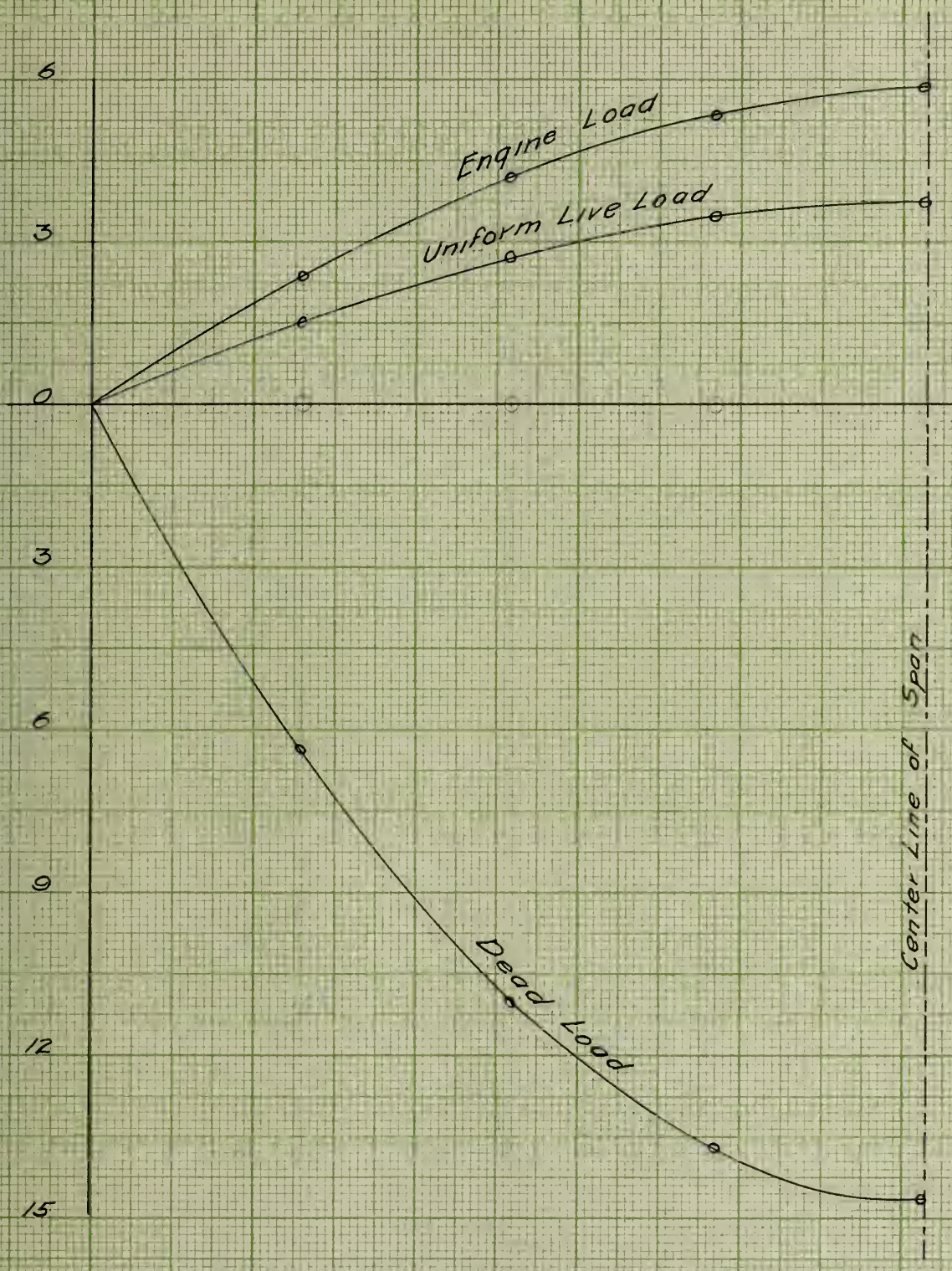


Fig 9 MOMENT DIAGRAMS
Scales Beam 1in = 5ft.
Curves 1in = 3000000 lb.-in.

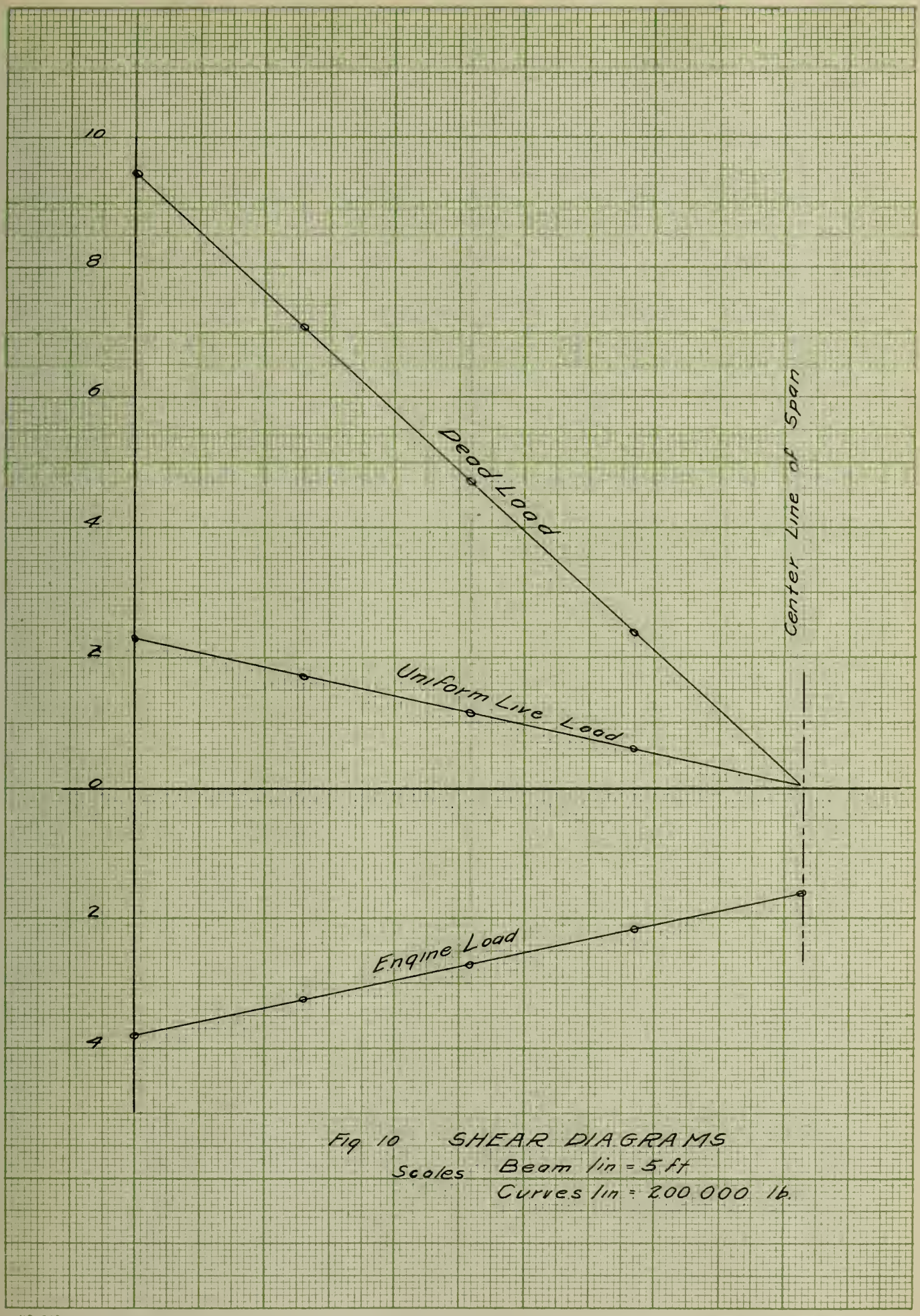


Fig 10 SHEAR DIAGRAMS

Scales Beam 1 in = 5 ft

Curves 1 in = 200 000 lb.

= 23,556,000 lb.in.

The area of the tensile steel is .02 X 30 X 53 = 31.8 sq. in.

" " " " compressive " " .01 X 30 X 53 = 15.9 " "

See Fig. 8.

The maximum shear occurs in the girder at the end when the engine load is just to the right of the support. The shear is equal to the reaction or 122,500 pounds. The area available to resist shear is 2.5 X 4.75 = 11.9 square feet or 143 square inch. The shear per square inch is $\frac{122500}{143}$ = 85.5 pounds, which is within the allowable limit of 90 pounds per square inch for reinforced concrete. Fig. 9 & 10 show shears and moments of girder. However, stirrups will be used to bond the materials together, their arrangement is shown in Fig. 8.

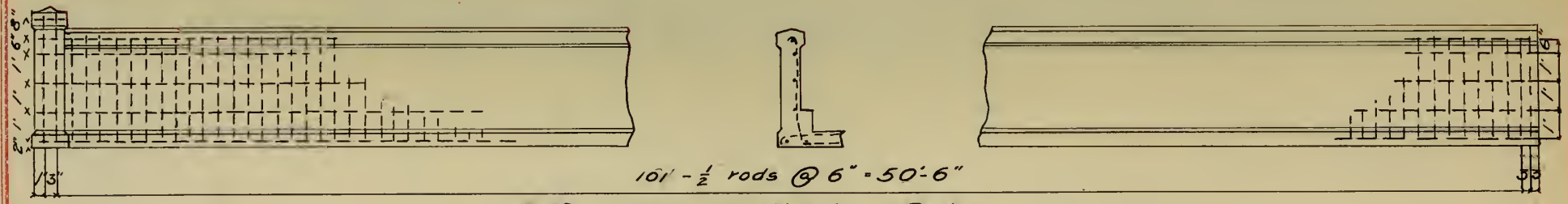


Fig. 8a Showing Steel in Railing

205-½ rods @ 3' = 51'-3"

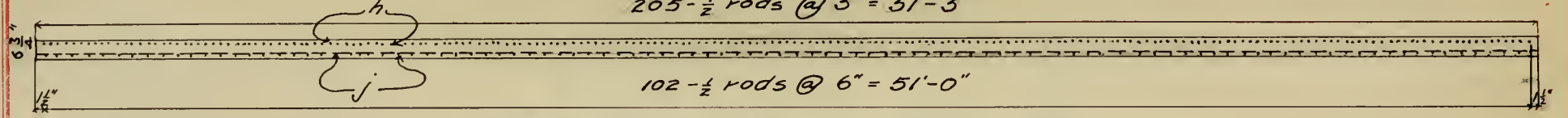


Fig. 8 Showing Steel in Cantilever Slab

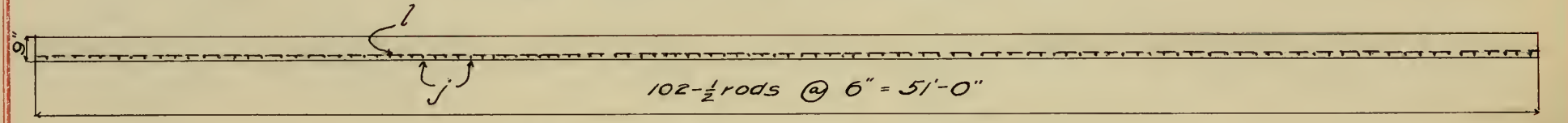


Fig 8 Showing Steel in Central Slab

24 @ 2' = 48'-0"

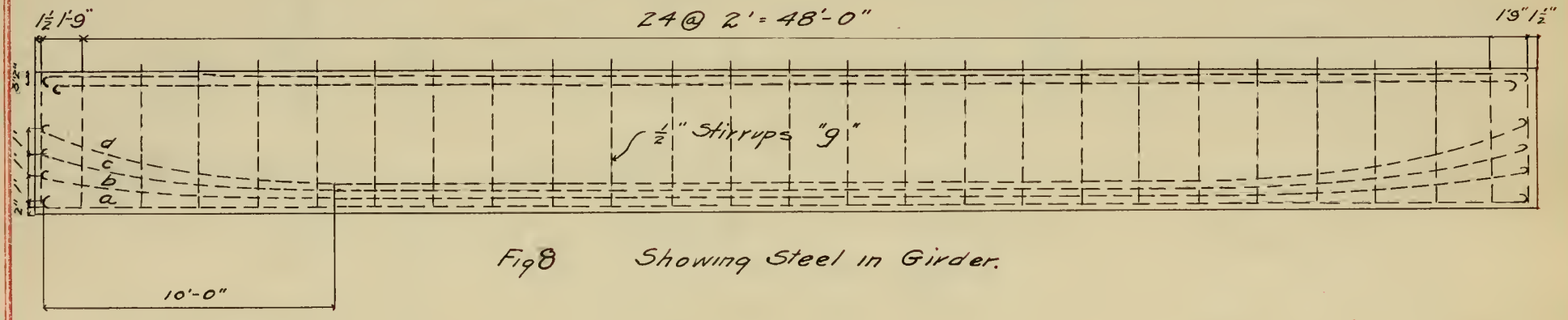


Fig 8 Showing Steel in Girder.

Art. 7. Design of Substructure.

The maximum load to be carried by any one of the piers is a full span length of the bridge and the engine load when directly above the pier. The center of gravity of the engine load will be assumed to act thru the long axis of the pier, 43,000 lbs. acting on the left girder and 5,000 lbs. on the right. See Fig. 11. The volume of the pier, is

19.5 X 7.5 = 732.5 cu. ft. footing

$\frac{16 + 72 + 131}{2} + 16 \times 15 = 1,765$ Total 2,497.5 cu. ft.

The total weight of the pier is 2,495.5 X 50 =375,000 pounds. The load on the pier due to one span length is 2 x 94,500 = 189,000 lbs.

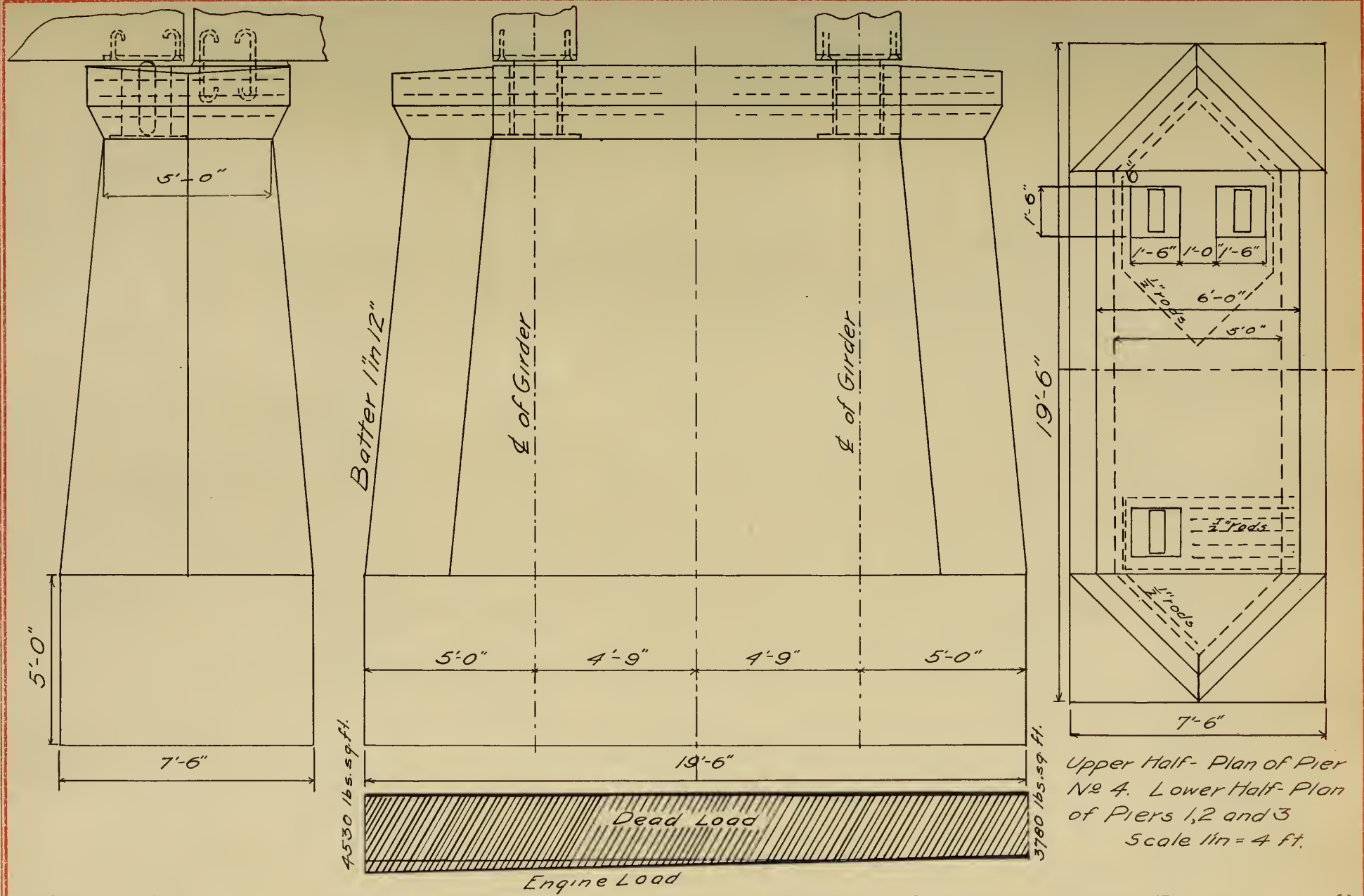
The engine load as stated before will be taken as acting entirely on the pier. The total weight to be carried by the pier is 375,000 + 189,000 + 48,000 = 612,000 lbs. The bearing area of the footing is 19.5 x 7.5 = 146.5 square feet. The average bearing on the soil per square foot will be $\frac{612,000}{146.5}$ =4,180 pounds. When the engine travels down the roadway within a half foot of the railing the variation of the pressure on the soil is as shown in the diagram in Fig. 10.

Table II gives the safe bearing power of several soils.

TABLE II

Kind of Material.	Safe Bearing Power in Tons per Sq. Ft. Min.	Max.
Clay in thick beds, always dry	6	8
" " " " moderately dry	4	6
" soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, dry compact and well cemented	4	6
" clean dry	2	4
Quicksand, alluvial soils, etc.	0.5	1

The bearing power of the soil upon which the piers are to rest may be safely assumed as 3 tons per sq. ft. If, however, the engineer in charge, upon investigation of the site, finds that this estimate is too high, the size of the footings may be increased, or piles may be driven to increase the bearing power.



Upper Half- Plan of Pier № 4. Lower Half- Plan of Piers 1, 2 and 3
Scale 1 in = 4 ft.

Fig. 11 Typical Design For Piers. Shaded Area Shows Variation of Pressure Due to Engine.

IV COST.

This estimate is merely an attempt to give a rough figure for the cost of the bridge. The data compiled are not based on actual figures for material, hauling, handling, etc. but more on bids for work of a similar character.

There are 153 cubic yards of concrete in the combined slabs and rails and 225 cubic yards in the girders, a total of 378 cubic yards of 1.2.4 mixture. This will require, 1 barrel of packed cement, 7.6 cubic feet of loose sand and 15.2 cubic feet of loose stone or gravel per cubic yard of concrete.

The price of cement at the present time is about $1.60 per barrel. Sand at the bridge site will come to $3.00 and stone $3.50 per cubic yard. This will make the price of materials per cubic yard of concrete about $4.00. For wheel sand, stone or gravel, mixing, hauling, handling, wetting, placing, tamping and spading $8.00 per cubic yard will be allowed, total $12.00 per cubic yard in place.

The concrete for the piers, mixed in a 1.3.6 proportion and without reinforcement, figured on the same basis, will be $10.00 per cubic yard in place.

The price of steel at the warehouse in Chicago is about $0.02 per pound. For freight, hauling placing, bending and wiring $0.02 additional, making a total of $0.04 per pound of steel in place.

Lumber for forms will be estimated at $33 per thousand feet. The amount required for flat surfaces for forms, will be 5,000 feet, for bracing 1,250 ft. a total of 6,250 feet, assuming that all lumber will be used twice. The total cost of the lumber will be $203 or $.25 per cubic yard of concrete. An additional cost

will be due to hauling, handling, building, tearing down and rebuilding the forms and $1.25 will be allowed, the total cost per cubic yard of concrete will be $1.50.

By reference to works of a similar character in hard clay, gravel and soft wet soil, the price for excavating will be $2.00 per cubic yard, to include sheeting and pumping. All items, weights, volumes, and costs are listed in Table III.

COST & BILL OF MATERIAL

Steel

Reference Letter	Number of Pieces	Size	Shape	Length per piece	total length	Weight per foot	Total Weight	Cost per lb. in place	Total cost	Remarks
f	25	1¼	□	53' 4"	1333	5.313	6750	$.04		
e	25	1¼	□	53 2	1330	5.313	6720	.04	270	
d	25	1¼	□	53 0	1328	5.313	6720	.04	270	
c	25	1¼	□	51 6	1290	5.313	6620	.04	265	
b	25	1¼	□	51 6	1290	5.313	6620	.04	265	
a	25	1¼	□	50 6	1263	5.313	6490	.04	260	
g	270	½	□	12 3	3310	.85	2820	.04	113	
h	2050	½	□	6 1	12500	.85	10630	.04	425	
j	1025	½	□	25 3	25900	.85	12000	.04	480	
l	130	½	□	50-9	6600	.85	5610	.04	225	
									2573	
P_1	10	½	2'6"x2'6"				1275	.05	64	4-1⅛" holes in each
P_2	10	½	2'6"x2'6"				1275	.04	51	
B_1	40	1	ϕ	1'-8"	67	2.67	178	.04	8	
B_2	40	1	ϕ	2'-0	80	2.67	214	.04	9	
R	10	special casting			6"x24"x16"		6000	.835	50	
						Concrete			182	

	Cu. yds Concrete	Cement cu.yd.	Sand cu.yd.	Stone cu.yd.	Cost per cu. yd.	Total	
Superstructure	153	21.80	43.70	87.50	12.00	1840	1:2:4 mixture
Girders	225	32.1	64.8	128.4	12.00	2700	1:2:4 mixture
Piers	464	46.4	139.2	2784	10.00	4640	1:3:6 mixture
Total	842					9180	

Forms and Excavation

For	842	cu.yds	concrete @ $1.50	1263
"	109	" "	of excavation with sheeting @ $2	218

Total cost 13416

20% of Cost for Profit, Engineer and Incidentals. 2683

$16 099

TABLE III

V LETTING OF CONTRACT.

All contractors wishing to bid on this work must be notified of the work by inserting an advertisement in the daily papers having the best circulation in the County, and also in the engineering papers. In this way, a large number of contractors will be reached. These notices must be inserted in the papers at least ten days before time of opening bids. To satisfy local contractors five notices, one of which is shown, will be posted in the vicinity of the bridge site.

BRIDGE LETTING.

Bids will be received at the court house in Urbana, Illinois, at 11 o'clock Saturday, April 5th, 1913, for a highway bridge across the Sangamon river about 1½ miles south of Fisher, Illinois. Bids may be sent by mail addressed: "County Clerk, Urbana, Ill., proposal for highway bridge for Condit and Newcomb townships." A certified check for $100 payable to the order of the chairman of the supervisors of Champaign county will be required with bids sent by mail or presented in person. Bridge to be completed on or before September 1st, 1913. Liquidated damages of $25.00 per day for each day thereafter.

The plans and specifications call for (1) two reinforced concrete floor steel spans of 128 feet 3 inch span, roadway 18 feet, with a new center pier, on piles if necessary, the old abutments being widened six feet and used; or (2) a reinforced concrete girder bridge of approximately five 52-foot spans, containing 603 cubic yards, more or less, of concrete and 84,000 pounds of reinforcement, more or less, if found necessary, 2,600 linear feet, more or less, of 20-foot piles.

Bidders are, in case of the steel spans, requested to submit a price for the structure complete, and also for sub and for superstructure only.

Plans and specifications are on file at the county clerk's office, Urbana, Illinois, or may be obtained from the engineer upon request by mail.

The right is reserved to reject any and all bids.

J. D. HOLTERMANN,
Chairman Bridge Committee.

I N G

; bids will be

ffice, Urbana, Illinois,

September 15th, 1913

of a bridge between

er the Sangamon River

linois.

yers, Clerk
Newcomb Twp.

ler, Clerk
Condit Twp.

NOTICE

BRIDGE LETTING

Notice is hereby given that bids will be received at the County Clerk's Office, Urbana, Illinois, at 11:00 o'clock A. M., Tuesday, September 15th, 1913 for the furnishing and erection of a bridge between Newcomb and Condit Townships, over the Sangamon River about ½ mile south of Fisher, Illinois.

R. L. Myers, Clerk
Newcomb Twp.

E. Ressler, Clerk
Condit Twp.

September 5, 1913.

Art. 10 Conclusion.

A bridge of this type, built without supervision other than that of the contractor is likely to be a failure. The contractors who usually bid on highway work of this kind are usually untechnically trained, and it is therefore essential for the full and complete success of this structure that the engineer in charge or a competent agent from the engineer's office be always present to supervise the erection.